APPENDICES

TOPIC 1: AQUEOUS REACTIONS

Appendix 1: Developing A Set Of Solubility Rules (Student BLM)

Develop your own procedure to create a set of solubility rules. The solutions the class will use include:

Set A: silver ions (Ag^+), barium ions (Ba^{2+}), sodium ions (Na^+), ammonium ions (NH_4^+), calcium ions (Ca^{2+}), chloride ions (Cl^-), carbonate ions (CO_3^{2-}), sulfate ions (SO_4^{2-}), nitrate ions (NO_3^-), and phosphate ions (PO_4^{3-})

Set B: zinc ions (Zn^{2+}), iron ions (Fe^{3+}), sodium ions (Na^+), magnesium ions (Mg^{2+}), potassium ions (K^+), chloride ions (Cl^-), hydroxide ions (OH^-), bromide ions (Br^-), carbonate ions (CO_3^{2-}), and acetate ions ($C_2H_3O_2^-$)

Hint: Before you begin mixing solutions, set up a grid to organize your observations.

Follow-up questions

1. Chemists have developed a set of solubility rules with respect to the solubility of anions with numerous cations.
    a) List the cations that did not form any precipitates.
    b) For each anion, list the cations with which it was insoluble (formed a precipitate).

2. List the set of solubility rules that you have developed.

Appendix 2: Developing A Set Of Solubility Rules—Teacher Notes

Solution sets of 25 mL dropper bottles:
Have student groups perform the lab using either Set A or Set B and then share their observations.

Notes: 1.0 mol/L solutions can be prepared instead of 0.1 mol/L solutions where appropriate. Involving students in the preparation of solutions is desirable. It may be clearer for students if the ions that participate in the reactions come from *separate solutions.* For instance, in "Set A", a solution of 0.1 mol/L NaCl could be the source of Na^+ ions, 0.1 mol/L Na_2CO_3 acts as the source of CO_3^{2-} ions and NH_4Cl can be used as a source for ammonium ions. These solutions would replace the "2 x 0.1 mol/L solutions of sodium carbonate (Na_2CO_3) labeled Na^+ and CO_3^{2-}"mentioned below. *The NH_4Cl is used for the NH_4^+ ions and the $(NH_4)_2SO_4$ is used as the source for SO_4^{2-} ions*. For Set B, NaCl can be used as a source for sodium ions and KCl can be used as a source for potassium ions.
If this strategy is not followed, students will no doubt observe "anomalous" precipitates (discrepant events) that were unexpected, and may be difficult to explain. Confusion could result, and so teachers are encouraged to proceed according to the level of difficulty desired for student explanations of results.

Set A:
1 x 0.1 mol/L solution of silver nitrate ($AgNO_3$) labeled Ag^+

2 x 0.1 mol/L solutions of barium chloride ($BaCl_2$) labeled Ba^{2+} and Cl^-

2 x 0.1 mol/L solutions of sodium carbonate (Na_2CO_3) labeled Na^+ and CO_3^{2-}

2 x 0.1 mol/L solutions of ammonium sulfate ($(NH_4)_2SO_4$) labeled NH_4^+ and SO_4^{2-}

2 x 0.1 mol/L solutions of calcium nitrate ($Ca(NO_3)_2$) labeled Ca^{2+} and NO_3^-

1 x 0.1 mol/L solution of potassium phosphate (K_3PO_4) labeled PO_4^{3-}

Set B:
1 x 0.1 mol/L solution of zinc acetate ($Zn(C_2H_3O_2)_2$) labeled Zn^{2+}

2 x 0.1 mol/L solutions of iron (III) chloride ($FeCl_3$) labeled Fe^{3+} and Cl^-

2 x 0.1 mol/L solutions of sodium hydroxide (NaOH) labeled Na^+ and OH^-

1 x 0.1 mol/L solutions of magnesium bromide ($MgBr_2$) labeled Mg^{2+}

1 x 0.1 mol/L solutions of sodium bromide (NaBr) labeled Br^-

2 x 0.1 mol/L solutions of potassium carbonate (K_2CO_3) labeled K^+ and CO_3^{2-}

1 x 0.1 mol/L solution of sodium acetate ($NaC_2H_3O_2$) labeled $C_2H_3O_2^-$

Probable results:

Set A:

	Cl^-	CO_3^{2-}	SO_4^{2-}	NO_3^-	PO_4^{3-}
Ag^+	PPT	PPT	PPT	N.R.	PPT
Ba^{2+}	N.R.	PPT	PPT	N.R.	PPT
Na^+	N.R.	N.R.	N.R.	N.R.	N.R.
NH_4^+	N.R.	N.R.	N.R.	N.R.	N.R.
Ca^{2+}	N.R.	PPT	PPT	N.R.	PPT

1.

a) The cations that did not form any precipitates were Na^+ and NH_4^+.

b) Cl^- formed a precipitate with Ag^+.
CO_3^{2-} formed a precipitate with Ag^+, Ba^{2+}, and Ca^{2+}.
SO_4^{2-} formed a precipitate with Ag^+, Ba^{2+}, and Ca^{2+}. Note Ag_2SO_4 is sparingly soluble so students may or may not see a precipitate.
NO_3^- did not form a precipitate with any of the cations.
PO_4^{3-} formed a precipitate with Ag^+, Ba^{2+}, and Ca^{2+}.

Set B:

	Cl^-	OH^-	Br^-	CO_3^{2-}	$C_2H_3O_2^-$
Zn^{2+}	N.R.	PPT	N.R.	PPT	N.R.
Fe^{3+}	N.R.	PPT	N.R.	N.R.	N.R.
Na^+	N.R.	N.R.	N.R.	N.R.	N.R.
Mg^{2+}	N.R.	PPT	N.R.	PPT	N.R.
K^+	N.R.	N.R.	N.R.	N.R.	N.R.

1.

a) The cations that did not form any precipitates were Na^+ and K^+.

b) Cl^- did not form a precipitate with any of the cations.
OH^- formed a precipitate with Zn^{2+}, Fe^{3+} and Mg^{2+}.
Br^- did not form a precipitate with any of the cations.
CO_3^{2-} formed a precipitate with Zn^{2+} and Mg^{2+}.
$C_2H_3O_2^-$ did not form a precipitate with any of the cations.

2. Solubility Rules

i) Most nitrate (NO_3^-) salts are soluble.

ii) Most salts containing the alkali metal ions (Li^+, Na^+, K^+, Rb^+, Cs^+) and the ammonium ion (NH_4^+) are soluble.

iii) Most chloride (Cl^-), bromide (Br^-), and iodide (I^-) salts are soluble. Notable exceptions are salts containing the ions Ag^+, Pb^{2+}, and Hg_2^{2+}.

iv) Most sulfate (SO_4^{2-}) salts are soluble. Notable exceptions are $BaSO_4$, $PbSO_4$, $HgSO_4$, and $CaSO_4$.

v) Most hydroxide salts are only slightly soluble. The important soluble hydroxides are NaOH and KOH. The compounds $Ba(OH)_2$, $Sr(OH)_2$, and $Ca(OH)_2$ are marginally soluble.

vi) Most sulfide (S^{2-}), carbonate (CO_3^{2-}), chromate (CrO_4^{2-}) and phosphate (PO_4^{3-}) salts are only slightly soluble.

Appendix 3: Solubility Rules

Negative ions	Positive Ions	Solubility
essentially all	alkali ions (Li^+, Na^+, K^+, Rb^+, Cs^+)	soluble
essentially all	hydrogen ion $H^+_{(aq)}$	soluble
essentially all	ammonium ion (NH_4^+)	soluble
nitrate, NO_3^-	essentially all	soluble
acetate, CH_3COO^-	essentially all (EXCEPT Ag^+)	soluble
chloride, Cl^- bromide, Br^- iodide, I^-	Ag^+, Pb^{2+}, Hg_2^{2+}, Cu^+, Tl^+	low solubility
	all others	soluble
sulfate, SO_4^{2-}	Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}, Ra^{2+}	low solubility
	all others	soluble
sulfide, S^{2-}	alkali ions, $H^+_{(aq)}$, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Ra^{2+}	soluble
	all others	low solubility
hydroxide, OH^-	alkali ions, $H^+_{(aq)}$, NH_4^+, Sr^{2+}, Ba^{2+}, Ra^{2+}, Tl^+	soluble
	all others	low solubility
phosphate, PO_4^{3-} carbonate, CO_3^{2-} sulfite, SO_3^{2-}	alkali ions, $H^+_{(aq)}$, NH_4^+	soluble
	all others	low solubility
chromate, CrO_4^{2-}	Ba^{2+}, Sr^{2+}, Pb^{2+}, Ag^+	low solubility
	all others	soluble

Appendix 4: Predicting Precipitation Reactions

Using a solubility table,

a) predict the products of the following reactions
b) write a balanced molecular equation and check the table for the solubility of the products
c) write a total ionic equation
d) write a net ionic equation

Example 1

$AlCl_3$ reacts with KOH

a) Al^{3+} combines with OH^- to form $Al(OH)_3$ and K^+ combines with Cl^- to form KCl

b) The balanced molecular equation will be

$$AlCl_{3(aq)} + 3\ KOH_{(aq)} \rightarrow Al(OH)_{3(s)} + 3\ KCl_{(aq)}$$

Notice from the solubility table that the Al^{3+} ion is insoluble with the OH^- ion, thus forming a precipitate.

c) Compounds that are written as aqueous are broken down to their respective cations and anions. Solids are written in molecular form.

$$Al^{3+}_{(aq)} + 3\ Cl^-_{(aq)} + 3\ K^+_{(aq)} + 3\ OH^-_{(aq)} \rightarrow Al(OH)_{3(s)} + 3\ K^+_{(aq)} + 3\ Cl^-_{(aq)}$$

d) Ions that are common to both sides of the reaction are called spectator ions. These ions are cancelled when writing the net ionic equation.

$$Al^{3+}_{(aq)} + \cancel{3\ Cl^-_{(aq)}} + \cancel{3\ K^+_{(aq)}} + 3\ OH^-_{(aq)} \rightarrow Al(OH)_{3(s)} + \cancel{3\ K^+_{(aq)}} + \cancel{3\ Cl^-_{(aq)}}$$

The net ionic equation would be

$$Al^{3+}_{(aq)} + 3\ OH^-_{(aq)} \rightarrow Al(OH)_{3(s)}$$

Example 2

$AgNO_3$ reacts with CaI_2

a) Ag^+ combines with I^- to form AgI and Ca^{2+} combines with NO_3^- to form $Ca(NO_3)_2$.
b) The balanced molecular equation will be

$$2\ AgNO_{3\ (aq)} + CaI_{2\ (aq)} \rightarrow 2\ AgI_{(s)} + Ca(NO_3)_{2\ (aq)}$$

Notice from the solubility table that the Ag^+ ion is insoluble with the I^- ion, thus forming a precipitate.

c) Compounds that are written as aqueous are broken down to their respective cations and anions. Solids are written in molecular form.

$$2\ Ag^{+}_{(aq)} + 2\ NO_3^{-}{}_{(aq)} + Ca^{2+}_{(aq)} + 2\ I^{-}_{(aq)} \rightarrow 2\ AgI_{(s)} + Ca^{2+}_{(aq)} + 2\ NO_3^{-}{}_{(aq)}$$

d) Ions that are common to both sides of the reaction are called spectator ions. These ions are cancelled when writing the net ionic equation.

$$2\ Ag^{+}_{(aq)} + \cancel{2\ NO_3^{-}{}_{(aq)}} + \cancel{Ca^{2+}_{(aq)}} + 2\ I^{-}_{(aq)} \rightarrow 2\ AgI_{(s)} + \cancel{Ca^{2+}_{(aq)}} + \cancel{2\ NO_3^{-}{}_{(aq)}}$$

The net ionic equation would be

$$2\ Ag^{+}_{(aq)} + 2\ I^{-}_{(aq)} \rightarrow 2\ AgI_{(s)}$$

Appendix 5 : Colour Chart

Ion	Symbol	Colour
Chrome (II)	Cr^{2+}	Blue
Chrome(III)	Cr^{3+}	Green
Cobalt (II)	Co^{2+}	Pink
Chromate	CrO_4^{2-}	Yellow
Bichromate	$Cr_2O_7^{2-}$	Orange
Copper(I)	Cu^{+}	Green
Copper(II)	Cu^{2+}	Blue
Iron(II)	Fe^{2+}	Green
Iron(III)	Fe^{3+}	Pale yellow
Manganese(II)	Mn^{2+}	Pink
Permanganate	MnO_4^{-}	Purple
Nickel(II)	Ni^{2+}	green

Appendix 6: Identifying Unknown Solutions – Teacher Notes and Preparation Guide

Present student groups with four unknown solutions. Their job will be to identify each using only a spot plate, a stir stick, a table of solubility rules, and the solutions themselves. The solution groups the class will use might include 0.1 mol/L solutions of:

Set 1: $Ba(NO_3)_2$, NaOH, Na_2CO_3, $CuSO_4$

Set 2: $Co(NO_3)_2$, Na_3PO_4, Na_2SO_4, $AgNO_3$

Set 3: $Cr_2(SO_4)_3$, $MnSO_4$, $Ba(NO_3)_2$, $Zn(NO_3)_2$

Set 4: $Fe(NO_3)_3$, KI, $Pb(NO_3)_2$, NaOH

Set 5: $NiSO_4$, Na_2CO_3, $MnSO_4$, NaCl

Set 6: $CuSO_4$, NaCl, Na_3PO_4, $Zn(NO_3)_2$

Students must correctly identify the four solutions and explain how they identified each of the solutions using the solubility rules.

1. Using a table that shows the colour of common ions in aqueous solutions, can you identify any of your unknowns based on this information?

2. Which solutions that you mixed formed a precipitate? Can you identify any of the unknown solutions based on this result?

3. Are there any reactions that have no precipitate formation? Can you identify any of the unknown solutions based on this result?

Preparation Guide
To prepare 0.1 mol / L solutions of each:

Set 1:
Solution 1: 2.613 grams of $Ba(NO_3)_2$ in 100 mL of solution

Solution 2: 0.40 grams of NaOH in 100 mL of solution

Solution 3: 1.06 grams of Na_2CO_3 in 100 mL of solution

Solution 4: 2.50 grams of $CuSO_4 \cdot 5H_2O$ in 100 mL of solution

Set 2:

Solution 1: 2.91 grams of $Co(NO_3)_2 \cdot 6H_2O$ in 100 mL of solution

Solution 2: 2.68 grams of $Na_3PO_4 \cdot 7H_2O$ in 100 mL of solution

Solution 3: 1.421 grams of Na_2SO_4 in 100 mL of solution

Solution 4: 1.699 grams of $AgNO_3$ in 100 mL of solution

Set 3:

Solution 1: 3.923 grams of $Cr_2(SO_4)_3$ in 100 mL of solution

Solution 2: 1.69 grams of $MnSO_4 \cdot H_2O$ in 100 mL of solution

Solution 3: 2.613 grams of $Ba(NO_3)_2$ in 100 mL of solution

Solution 4: 2.97 grams of $Zn(NO_3)_2 \cdot 6H_2O$ in 100 mL of solution

Set 4:

Solution 1: 4.04 grams of $Fe(NO_3)_3 \cdot 9H_2O$ in 100 mL of solution

Solution 2: 1.66 grams of KI in 100 mL of solution

Solution 3: 3.312 grams of $Pb(NO_3)_2$ in 100 mL of solution

Solution 4: 0.40 grams of NaOH in 100 mL of solution

Set 5:

Solution 1: 2.63 grams of $NiSO_4 \cdot 6H_2O$ in 100 mL of solution

Solution 2: 1.06 grams of Na_2CO_3 in 100 mL of solution

Solution 3: 1.69 grams of $MnSO_4 \cdot H_2O$ in 100 mL of solution

Solution 4: 0.584 grams of NaCl in 100 mL of solution

Set 6:

Solution 1: 2.50 grams of $CuSO_4 \cdot 5H_2O$ in 100 mL of solution

Solution 2: 0.584 grams of NaCl in 100 mL of solution

Solution 3: 2.68 grams of $Na_3PO_4 \cdot 7H_2O$ in 100 mL of solution

Solution 4: 2.97 grams of $Zn(NO_3)_2 \cdot 6H_2O$ in 100 mL of solution

Appendix 7: Process Notes for Writing Net Ionic Equations

Step 1: Solve the problem, showing all steps	Step 2: Use words to describe each step of the solution process
$Na_2S + FeSO_4 \rightarrow Na_2SO_4 + FeS$	Step 1: Predict the products of the double displacement reaction and ensure that the equation is balanced.
$Na_2S_{(aq)} + FeSO_{4(aq)} \rightarrow Na_2SO_{4(aq)} + FeS_{(s)}$	Step 2: Use “aq” and “s” to identify each species as being soluble or slightly soluble (i.e. write the molecular equation)
$2Na^+_{(aq)} + S^{2-}_{(aq)} + Fe^{2+}_{(aq)} + SO_4{}^{2-}_{(aq)} \rightarrow 2Na^+_{(aq)} + SO_4{}^{2-}_{(aq)} + FeS_{(s)}$	Step 3: Write the ionic equation by breaking up soluble species into their ions.
$\cancel{2Na^+_{(aq)}} + S^{2-}_{(aq)} + Fe^{2+}_{(aq)} + \cancel{SO_4{}^{2-}_{(aq)}} \rightarrow \cancel{2Na^+_{(aq)}} + \cancel{SO_4{}^{2-}_{(aq)}} + FeS_{(s)}$	Step 4: Cancel out all spectator ions and rewrite the equation.
$S^{2-}_{(aq)} + Fe^{2+}_{(aq)} \rightarrow FeS_{(s)}$	This gives the net ionic equation.

Appendix 8: Process Notes for Writing Net Ionic Equations (Student BLM)

Step 1: Solve the problem, showing all steps	**Step 2: Use words to describe each step of the solution process**
$BaCl_2 + Na(PO_4)_3 \rightarrow$	Step 1: Predict the products of the double displacement reaction and ensure that the equation is balanced. Step 2: Use "aq" and "s" to identify each species as being soluble or slightly soluble (i.e. write the molecular equation) Step 3: Write the ionic equation by breaking up soluble species into their ions. Step 4: Cancel out all spectator ions and rewrite the equation. This gives the net ionic equation.

Appendix 9: Titration Lab

Titrations are procedures which are usually used to determine the unknown concentrations of substances. In this lab, you will add drops of a known concentration of sodium hydroxide to a beaker containing a known concentration of sulfuric acid until neutralization occurs. The number of moles of each reactant can then be calculated from the volumes present, so that their ratio can be compared to the ratio of coefficients in the balanced equation.

Materials:

1-50 mL beaker
3 micropipettes
Phenolphthalein indicator
10 mL graduated cylinder
distilled water
0.1 mol / L NaOH
0.1 mol / L H_2SO_4

Procedures:

1. Using the 10 mL graduated cylinder and a micropipette, count and record the number of drops required to obtain 1.0 mL of distilled water. Repeat this process a total of three times.
   NOTE: For the best, most reproducible results, hold the micropipette vertically, and squeeze the bulb slowly and gently. Avoid introducing air bubbles into the stem of the pipette, as they will result in half or quarter drops.
2. Add 5 mL of distilled water, and one drop of phenolphthalein indicator to a 50 mL beaker. Swirl the beaker well.
3. Using a second micropipette (to avoid contamination of the solutions), add 20 drops of 0.1 mol / L H_2SO_4 to the beaker. Swirl the solution carefully.
4. Using a third micropipette, add the 0.1 mol / L NaOH drop by drop, until the addition of one drop of the base permanently changes the colour of the solution. Be sure to gently swirl the beaker after each drop is added. Record the number of drops required to reach the endpoint of the titration.
   NOTE: The endpoint of the titration is when one drop of an acid or base permanently changes the colour of the indicator used in the titration.
5. Rinse the contents of the beaker down the sink with plenty of water (the final rinse should be with distilled water), and repeat steps 2 through 4 a total of three times.
   *The trials should agree with one another to within one drop. If you make a mistake, miss the endpoint, or lose count of the drops, perform another trial. Do not erase the results, but make note of what went wrong.

Qualitative observations

--Describe each solution before reaction.
--Describe the solution after adding the drops of phenolphthalein.

Quantitative Data Tables

Trial	Drops of water in 1.0 mL
1	
2	
3	
Average:	

Volume of water used (mL)	Drops of Sulfuric Acid	Volume of Sulfuric Acid (mL)	Drops of Sodium Hydroxide	Volume of Sodium Hydroxide (mL)
5	20			
5	20			
5	20			
Average:				

Calculations

1. Write a balanced molecular equation for the reaction.
2. Draw a molecular representation of the balanced reaction.
3. Calculate the average number of drops required to obtain 1.0 mL of distilled water.
4. Using the data obtained in Step 2, calculate the volume of NaOH added in each trial.
5. Calculate the average number of moles of NaOH required to neutralize the sample of H_2SO_4.
6. Using the data obtained in Step 2, calculate the volume of H_2SO_4 added in each trial.
7. Using your balanced equation, determine the average number of moles present in the sample of H_2SO_4.
8. Use the coefficients in the balanced equation to determine the ratio of moles between the sodium hydroxide and the sulfuric acid.

9. Use the number of moles obtained in steps 4 and 5 to determine the ratio of moles between the sodium hydroxide and the sulfuric acid.

Conclusion

State the stoichiometric relationship between the sodium hydroxide and the sulfuric acid as has been previously demonstrated to you in examples.

Questions

1. a) Write a balanced molecular equation for the reaction between barium hydroxide and sulfuric acid.
   b) Use the coefficients in the balanced equation to calculate the volume of barium hydroxide required to react with 20 mL of sulfuric acid.

2. a) Write a balanced molecular equation for the reaction between aluminum hydroxide and sulfuric acid.
   b) Use the coefficients in the balanced equation to calculate the volume of aluminum hydroxide required to react with 30 mL of sulfuric acid.

Sources of Error

What possible errors could have occurred in your lab activity?

Appendix 10: Titration Lab - (Teacher Notes)

Purpose: To demonstrate the stoichiometry of a neutralization reaction between a strong acid and a strong base.

Qualitative observations

Distilled water	clear, colourless liquid
Sulfuric acid	clear, colourless liquid
Sodium hydroxide	clear, colourless liquid
Phenolphthalein	clear, colourless liquid

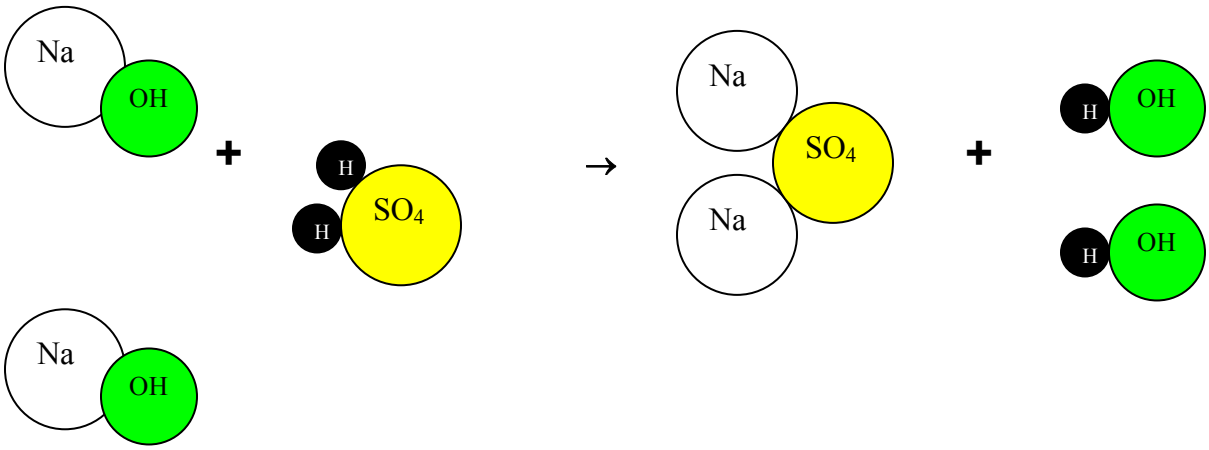
Quantitative Data Tables

Trial	Drops of water in 1.0 mL
1	23
2	24
3	23
Average:	23

Volume of water used (mL)	Drops of Sulfuric Acid	Volume of Sulfuric Acid (mL)	Drops of Sodium Hydroxide	Volume of Sodium Hydroxide (mL)
5	20	0.858	69	2.96
5	20	0.858	68	2.92
5	20	0.858	70	3.00
Average:	20	0.858	69	2.96

Calculations

1. $2NaOH_{(aq)} + H_2SO_{4(aq)} \rightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)}$
2. Molecule size is not a true representation of the actual size of the compound.



3. 23 + 24 + 23 / 3 = 23.3 drops
4. volume NaOH = (1 mL / 23.3 drops) × 69 drops = 2.96 mL of NaOH
5. moles NaOH = 0.10 mole / L × 2.96 × 10^{-3} L = .000296 moles NaOH
6. volume H_2SO_4 = (1 mL / 23.3 drops) × 20 drops = 0.858 mL of H_2SO_4
7. moles H_2SO_4 = 0.10 mole / L × 0.858 × 10^{-3} L = .0000858 moles H_2SO_4
8. coefficient NaOH / coefficient H_2SO_4 = 2 / 1 = 2
9. moles NaOH / moles H_2SO_4 = .000296 / .0000858 = 3.45

Conclusion

Answers will vary. For instance, the stoichiometric relationship between the sodium hydroxide and the sulfuric acid in the balanced equation is 2 to 1, while the experimental relationship was 3.45 to 1.

Questions

1. a) $Ba(OH)_{2(aq)} + H_2SO_{4(aq)} \rightarrow BaSO_{4(aq)} + 2H_2O_{(l)}$
   b) The volume of barium hydroxide required to react with 20 mL of sulfuric acid is 20 mL.

2. a) $2Al(OH)_{3(aq)} + 3H_2SO_{4(aq)} \rightarrow Al_2(SO_4)_{3(aq)} + 6H_2O_{(l)}$
   b) The volume of aluminum hydroxide required to react with 30 mL of sulfuric acid is 20 mL.

Sources of Error

Some sources of error could include calibration of the micropipette and graduated cylinder as well as the accuracy of the concentrations of the solutions used.

Appendix 11: Process Notes for Balancing Neutralization Reactions

Step 1: Solve the problem, showing all the steps.	Step 2: Use words to describe each step of the solution process.
$H_2SO_4 + NaOH \rightarrow Na_2SO_4 + H_2O$	Step 1: Predict the products of the neutralization reaction. Remember that a salt and water are formed.
$H_2SO_{4(aq)} + 2\ NaOH_{(aq)} \rightarrow Na_2SO_{4\ (aq)} + 2\ H_2O_{(l)}$	Step 2: Ensure that the equation is balanced. Use "aq" and "l" to identify each species as being soluble or slightly soluble (i.e. write the molecular equation)
$2\ H^+_{(aq)} + SO_4^{2-}{}_{(aq)} + 2\ Na^+_{(aq)} + 2\ OH^-_{(aq)} \rightarrow$ $2\ Na^+_{(aq)} + SO_4^{2-}{}_{(aq)} + 2\ H_2O_{(l)}$	Step 3: Write a total ionic equation, showing all ions that are in solution.
$\cancel{2}\ H^+_{(aq)} + \cancel{SO_4^{2-}}_{(aq)} + \cancel{2\ Na^+}_{(aq)} + \cancel{2}\ OH^-_{(aq)} \rightarrow$ $\cancel{2\ Na^+}_{(aq)} + \cancel{SO_4^{2-}}_{(aq)} + \cancel{2}\ H_2O_{(l)}$	Step 4: Cancel the spectator ions.
$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$	Step 5: Write the net ionic equation.

Appendix 12: Test Tube Mystery Lab

Chemists, like detectives, attempt to identify unknowns through a process of careful and creative analysis. This usually involves observing the colours, odours, and reactions of the unknown substances and comparing them with those of known substances. In this experiment, you will try to identify twelve different chemical compounds by reacting them with each other, observing the results, and comparing the results with the known characteristics of some common chemicals.

The twelve chemicals are (in no particular order)--potassium chromate (K_2CrO_4), aluminum chloride ($AlCl_3$), sodium carbonate (Na_2CO_3), sodium acetate ($NaCH_3COO$), hydrochloric acid (HCl), sodium hydroxide (NaOH), ammonia (NH_4OH), iron (III) nitrate ($Fe(NO_3)_3$), silver nitrate ($AgNO_3$), copper (II) sulfate ($CuSO_4$), nickel (II) chloride ($NiCl_2$), and lead (II) nitrate ($Pb(NO_3)_2$).

Before starting the lab, you will have to do extensive research on the characteristic colours of the solutions, any distinguishing odours, their flame test colours, and the colours of any precipitates that may be created through the combination of each different species. Your written plan (which must be shared in three classes) must include a data table grid that includes each species, solution and flame test colours, the colours of potential precipitates, and any other information that you feel will help to identify your unknowns.

On the day of the lab, you will be provided with twelve test tubes containing 8 mL each of different solutions, well plates, stir sticks, cotton swabs / flame test wires / moist wooden splints, Bunsen burners, matches, *litmus paper*, 10 micropipettes, gloves, and distilled water. Avoid running out of your samples, as you will not be provided with any more. And do not assume that solution sets other groups are using have been numbered in the same way--they are not!

After recording all of your observations in the lab, you will be provided with time to attempt an identification for each of the unknowns. A formal lab write-up must include a logical explanation of how you determined the identity of each test tube. This will include net ionic equations for any precipitates you saw.

A few friendly words of advice:

All solutions must be treated as if they were poisonous and corrosive. Avoid inhaling any fumes. Some reactions may occur very quickly, while others will occur more slowly. Observe each reaction for at least two minutes before disposing of the products. Gas evolution (bubbling) will be immediate. Rinse off your stir stick after each use. As it will be limited, time is of the essence. Use your time wisely!

Appendix 13: The Twelve Test Tube Mystery-Preparation Guide

Teachers can prepare these solutions in advance or students can prepare these solutions as part of outcome C11-4-15 (at Grade 11). Prepare a solution, given the amount of solute (in grams), and the volume of solution (in milliliters), and determine the concentration in moles / litre.

Materials:
Well plates, stir sticks, cotton swabs / flame test wires / moist wooden splints, Bunsen burners, matches, litmus paper, micropipettes (10 per group), gloves, distilled water, test tube rack, test tubes (12 x 10/group = 120 test tubes), test tube stoppers or plastic wrap can be used to cover the test tubes

100 mL solutions of the following:
0.2 mol / L K_2CrO_4 to prepare dissolve 3.88 grams of K_2CrO_4 in 100 mL of distilled water
1.0 mol / L $AlCl_3 \cdot 6H_2O$ to prepare dissolve 24.14 grams of $AlCl_3$ in 100 mL of distilled water
1.0 mol / L Na_2CO_3 to prepare dissolve 10.6 grams of Na_2CO_3 in 100 mL of distilled water
1.0 mol / L $NaCH_3COO \cdot 3H_2O$ to prepare dissolve 13.61 g of $NaCH_3COO$ in 100 mL of distilled water
6.0 mol / L HCl to prepare mix 49.6 mL in 100 mL of distilled water
6.0 mol / L NaOH to prepare dissolve 24.0 grams of NaOH in 100 mL of distilled water
6.0 mol / L NH_4OH to prepare mix 40.5 mL in 100 mL of distilled water
0.1 mol / L $Fe(NO_3)_3 \cdot 9H_2O$ to prepare dissolve 4.04 g of $Fe(NO_3)_3 \cdot 9H_2O$ in 100 mL of distilled water
0.1 mol / L $AgNO_3$ to prepare dissolve 1.70 grams of $AgNO_3$ in 100 mL of distilled water
0.1 mol / L $CuSO_4$ to prepare dissolve 2.50 grams of $CuSO_4 \cdot 5H_2O$ in 100 mL of distilled water
0.1 mol / L $NiCl_2 \cdot 6H_2O$ to prepare dissolve 2.38 grams of $NiCl_2$ in 100 mL of distilled water
0.1 mol / L $Pb(NO_3)_2$ to prepare dissolve 3.31 grams of $Pb(NO_3)_2$ in 100 mL of distilled water

100 mL solutions should be prepared in advance.
Test tubes can be pre-labelled with the information, set #1, test tube #1, etc.
Students are given an 8 – 10 mL sample of each solution (12 different test tubes) that are contained in a test tube rack.
A suggested teacher key is given for setting up each set of test tubes.

Teacher Solution Set Key

Substance	Group 1 and Group 9	Group 2 and Group 10	Group 3 and Group 6	Group 4 and Group 7	Group 5 and Group 8
K_2CrO_4	3	1	2	3	4
$AlCl_3$	5	5	6	7	8
Na_2CO_3	6	9	10	11	12
$NaCH_3COO$	1	4	1	2	3
HCl	11	8	5	6	7
NaOH	4	12	9	10	11
NH_4OH	7	3	4	1	2
$Fe(NO_3)_3$	10	7	8	5	6
$AgNO_3$	2	11	12	9	10
$CuSO_4$	8	2	3	4	1
$NiCl_2$	12	6	7	8	5
$Pb(NO_3)_2$	9	10	11	12	9

Appendix 14: TEACHER KEY 1

Example of what students could have prepared before doing the lab:

	K_2CrO_4	$AlCl_3$	Na_2CO_3	$NaCH_3COO$	HCl	NaOH	NH_4OH	$Fe(NO_3)_3$	$AgNO_3$	$CuSO_4$	$NiCl_2$	$Pb(NO_3)_2$
K_2CrO_4		NP	NP	NP	NP	NP	NP	NP	Ag_2CrO_4	NP	NP	$PbCrO_4$
$AlCl_3$			$Al_2(CO_3)_3$	NP	NP	$Al(OH)_3$	$Al(OH)_3$	NP	AgCl	NP	NP	$PbCl_2$
Na_2CO_3				NP	gas	NP	NP	$Fe_2(CO_3)_3$	$AgCO_3$	$CuCO_3$	$NiCO_3$	$PbCO_3$
$NaCH_3COO$					NP	NP	NP	NP	$AgCH_3COO$	NP	NP	NP
HCl						NP	NP	NP	AgCl	NP	NP	$PbCl_2$
NaOH							NP	$Fe_2(OH)_3$	AgOH	$Cu(OH)_2$	$Ni(OH)_2$	$Pb(OH)_2$
NH_4OH								$Fe_2(OH)_3$	AgOH	$Cu(OH)_2$	$Ni(OH)_2$	$Pb(OH)_2$
$Fe(NO_3)_3$									NP	NP	NP	NP
$AgNO_3$										Ag_2SO_4 ?	AgCl	NP
$CuSO_4$											NP	$PbSO_4$
$NiCl_2$												$PbCl_2$
$Pb(NO_3)_2$												

Appendix 15: Teacher Key 2

Substance	Identifying colour / odour of solution	Colour in litmus paper	Flame test colour	Reacts with	To make	Colour of ppt
K_2CrO_4	yellow	blue	violet	$AgNO_3$ $Pb(NO_3)_2$	Ag_2CrO_4 $PbCrO_4$	brick red yellow
$AlCl_3$		neutral		Na_2CO_3 NaOH $AgNO_3$ $Pb(NO_3)_2$	$Al_2(CO_3)_3$ $Al(OH)_3$ AgCl $PbCl_2$	white white white* yellow
Na_2CO_3		blue	yellow	HCl $Fe(NO_3)_3$ $AgNO_3$ $CuSO_4$ $NiCl_2$ $Pb(NO_3)_2$ $AlCl_3$	bubbles $Fe(CO_3)_3$ $AgCO_3$ $CuCO_3$ $NiCO_3$ $PbCO_3$ $Al_2(CO_3)_3$	bubbles white white* white white white white
$NaCH_3COO$		blue	yellow	$AgNO_3$	$AgCH_3COO$	white*
HCl		pink		$AgNO_3$ $Pb(NO_3)_2$ Na_2CO_3	AgCl $PbCl_2$ bubbles	white* yellow bubbles
NaOH		blue		$Fe(NO_3)_3$ $AgNO_3$ $CuSO_4$ $NiCl_2$ $Pb(NO_3)_2$ $AlCl_3$	$Fe(OH)_3$ AgOH $Cu(OH)_2$ $Ni(OH)_2$ $Pb(OH)_2$ $Al(OH)_3$	white brown white white white white
NH_4OH	strong odour	blue		$Fe(NO_3)_3$ $AgNO_3$ $CuSO_4$ $NiCl_2$ $Pb(NO_3)_2$ $AlCl_3$	$Fe(OH)_3$ AgOH $Cu(OH)_2$ $Ni(OH)_2$ $Pb(OH)_2$ $Al(OH)_3$	white brown* white white white white
$Fe(NO_3)_3$	pale yellow	neutral		Na_2CO_3 NaOH	$Fe_2(CO_3)_3$ $Fe(OH)_3$	white white/brown
$AgNO_3$		neutral		$NiCl_2$ K_2CrO_4 $AlCl_3$ Na_2CO_3 $NaCH_3COO$ HCl NaOH $CuSO_4$ (?)	AgCl Ag_2CrO_4 AgCl Ag_2CO_3 $AgCH_3COO$ AgCl AgOH Ag_2SO_4 (?)	white* brick red white* white* white* white* brown white*
$CuSO_4$	blue	neutral	bluish-green	$Pb(NO_3)_2$ Na_2CO_3 NaOH	$PbSO_4$ $CuCO_3$ $Cu(OH)_2$	white white white

$NiCl_2$	green / green-blue	neutral		$Pb(NO_3)_2$ Na_2CO_3 NaOH $AgNO_3$	$PbCl_2$ $NiCO_3$ $Ni(OH)_2$ AgCl	yellow white white white*
$Pb(NO_3)_2$		neutral	bluish-white	K_2CrO_4 $AlCl_3$ Na_2CO_3 HCl NaOH $CuSO_4$ $NiCl_2$	$PbCrO_4$ $PbCl_2$ $PbCO_3$ $PbCl_2$ $Pb(OH)_2$ $PbSO_4$ $PbCl_2$	yellow yellow white yellow white white yellow

*Most Ag precipitates start out a white to grayish white colour, but turn purple / brown / black over time.

Appendix 16: Oxidation-Reduction Compare and Contrast Frame

Oxidation	Reduction
Historical Definition: Example:	Historical Definition: Example:
Present Definition: Example:	Present Definition: Example:
Mnemonic Device:	Mnemonic Device:
When Balancing a Redox Reaction: One substance is _____ and it is also the _____ agent. Its oxidation number _____.	When Balancing a Redox Reaction: One substance is _____ and it is also the _____ agent. Its oxidation number _____.

Appendix 17: Compare and Contrast Frame – Sample Response

Oxidation	**Reduction**
Historical Definition: Gain of oxygen Example: $4\ Fe + 3\ O_2 \rightarrow 2\ Fe_2O_3$ $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$	Historical Definition: Loss of oxygen Example: $2\ Fe_2O_3 + 3\ C \rightarrow 4\ Fe + 3\ CO_2$
Present Definition: Loss of Electrons Example: $Mg + S \rightarrow MgS$ (Mg undergoes oxidation)	Present Definition: Gain of Electrons Example: $Mg + S \rightarrow MgS$ (Sulfur undergoes reduction)
Mnemonic Device: OIL	Mnemonic Device: RIG
When Balancing a Redox Reaction: One substance is <u>oxidized</u> and it is also the <u>reducing</u> agent. Its oxidation number <u>increases</u>.	When Balancing a Redox Reaction: One substance is <u>reduced</u> and it is also the <u>oxidizing</u> agent. Its oxidation number <u>decreases.</u>

Appendix 18: Oxidation Numbers Rules

Rule 1: The oxidation number of any free atom (or multiple of itself) is 0.

Examples: C = 0 H_2 = 0 O_2 = 0

Rule 2: An ion's (or complex ion's) oxidation number is its charge.

Examples: Na^+ = +1 P^{3+} = +3 S^{2-} = -2

Rule 3: In a compound the sum of all of the oxidation numbers of each part must equal the total charge of that compound or complex ion.

Examples:	NaCl	$CaCl_2$	SO_4^{2-}
	+1 -1	+2 -2	+6 –2 –2 –2 –2 = -2

Rule 4: Hydrogen's oxidation number is +1 except in metal hydrides where H is the anion (ex. CaH_2 or LiH) where it is -1.

Rule 5: The oxidation number of oxygen is -2, except in peroxides (ie. H_2O_2, Na_2O_2) where it is -1, and when in combination with fluorine (O = +2).

Appendix 19: Sample Assignment

In order for you to learn more about the redox reactions taking place around you, groups of no more than 3 students will be asked to prepare a written report and to make an oral presentation on one of the following topics.

a) rocket fuels
b) fireworks
c) household bleach (i.e., stain removal and chlorination)
d) photography
e) metal recovery from ores
f) steel making
g) aluminum recycling
h) fuel cells
i) batteries
j) tarnish removal
k) fruit clocks
l) forensic blood detection using luminal
m) corrosion i.e., rusting-the process and methods of prevention
n) chemiluminescence/bioluminescence
o) electrolytic cleaning
p) electrodeposition
q) photochemical etching
r) antioxidants / preservatives

Your group's written project (of approximately 1 page) will be handed in to your teacher the day before your oral presentation. (*Dates will be determined at the beginning of the Electrochemistry unit), so that the written report can be copied for your classmates.

The oral presentation should be approximately 10 min long and will be teacher evaluated. It will be followed by a brief question period (no longer than 5 min) in which the audience may ask clarifying questions.

Please refer to the attached rubrics for a more detailed list of requirements and the grading schemes for both the oral presentation and the written report.

Available resources:
a) school library
b) internet
c) old text books (see teacher)
d) e-mail (perhaps a scientist can assist you0
e) phone book (e.g., someone at the RCMP Forensics lab may have pamphlets to send you on information relevant to luminal tests)
f) university libraries or public libraries

Appendix: Outcome 1-12

Names: _____
_____
_____

Appendix 20: Practical Applications of Redox Reactions – Sample Rubrics

Group Report

0	1	2	3	4	5	Total Points Awarded	Total Possible Points
General Requirements							
The report does not fulfill any of the requirements	The report fulfills one of the five requirements	The report fulfills two of the five requirements	The report fulfills three of the five requirements	The report fulfills four of the five requirements	-The report includes a title page. -The report is word processed. -The report is double spaced. -The report includes an alphabetized bibliography. -At least five sources are cited in the bibliography.		
Content / Information							
The report does not include any of the five requirements	The report fulfills one of the five requirements	The report fulfills two of the five requirements	The report fulfills three of the five requirements	The report fulfills four of the five requirements	-The information presented is clear, accurate, and concise. -All relevant information is completely presented and easily understood -The report includes all redox reactions being utilized by the application. -The report identifies all substances being oxidized and reduced, as well as any oxidizing and reducing agents. -The report describes how the relevant redox reactions are used by man / nature.		

0	1	2	3	4	Total Points Awarded	Total Possible Points
Organization						
The report does not fulfill any of the requirements	The report fulfills one of the four requirements	The report fulfills two of the four requirements	The report fulfills three of the four requirements	-A clear and concise introduction includes a description of the topic of interest. -The body follows a logical pattern. -There are smooth transitions between paragraphs. -The conclusion includes a brief summary of the topic's connection to redox chemistry.		
Mechanics (grammar, Spelling, and Punctuation)						
Frequent errors demonstrate no sign of proofreading	Six errors found.	Four errors found	Two errors found	No errors. Great Job!		
Visual Aids (pictures, charts, diagrams)						
The visual aids do not fulfill the requirements.	The visual aids fulfill one of the three requirements	The visual aids fulfill two of the three requirements	-Time and effort was obviously put forth in the preparation of the visual aids. -Aids used in the report are neat and organized. -The aids help make the application more easily understood.			
Creativity						
The report shows no creativity.		The report shows some creativity		The creativity in the report is "above and beyond"		

Appendix: Outcome 1-11

Names: _____
_____
_____

Practical Applications of Redox Reactions

Project Rubric

Group Presentation

0	1	2	3	4	5	6	Total Points Awarded	Total Possible Points
Content / Information								
The content does not include any of the four requirements	The content fulfills one of the four requirements	The content fulfills two of the four requirements	The content fulfills three of the four requirements	-The information presented is clear, accurate, and concise. -All relevant information is completely presented. -All redox reactions are included. -An accurate description of the application is presented.				
Presentation								
The presenters do not fulfill any of the six requirements	The presenters fulfill one of the six requirements	The presenters fulfill two of the six requirements	The presenters fulfill three of the six requirements	The presenters fulfill one of the six requirements	The presenters fulfill five of the six requirements	-All presenters make eye contact -All presenters contribute equally to the presentation. -All presenters speak with clear, modulated voices. -All presenters speak confidently without referring to their notes. -All presenters demonstrate an interest in and an enthusiasm for the topic -The presentation involved the audience		

0	1	2	3	Total Points Awarded	Total Possible Points
Organization					
The presentation does not fulfill any of the requirements	The presentation fulfills one of the four requirements	The presentation fulfills two of the three requirements	-An explicit introduction and conclusion is included. -The presentation follows a logical pattern -There are smooth transitions between sections.		
Pace					
The presentation is paced such that the audience cannot keep up with the information presented, or it is provided too slowly			-The presentation is neither too fast nor too slow.		
Visual Aids (models, diagrams, Powerpoint presentations, video, demonstrations)					
The visual aids do not fulfill the requirements.	The visual aids fulfill one of the three requirements	The visual aids fulfill two of the three requirements	-Time and effort was obviously put forth in the preparation of the visual aid(s). -Aids used in the presentation are neat and organized. -The aids help make the application more easily understood.		
Creativity					
The presentation fails to capture student interest at any time.	The presentation fails to capture and maintain the interest of all students	Some students appear distracted at times during the presentation.	The presentation keeps students interested throughout.		
Understanding Of The Topic					
The presenters have a poor understanding of the material. No audience questions could be answered.	The presenters lack a complete understanding of the material. Very few audience questions can be answered.	The presenters convey a good understanding of the material, but cannot completely answer all audience questions.	The presenters convey an outstanding understanding of the material by answering audience questions clearly and appropriately.		

0	1	2	3	4	Total Points Awarded	Total Possible Points
Test questions						
The test questions / answers do not fulfill any of the requirements, or are not included with the report	The test questions / answers fulfill one of the four requirements	The test questions / answers fulfill two of the four requirements	The test questions / answers fulfill three of the four requirements	-Five different questions about the topic are included -An answer key is included. -Questions test different parts of the presentation / report. -Answers to the questions are of different lengths.		
Group Evaluation						
The group did not use the available time appropriately. Group members did not contribute equally to the report.	The group misused some of the available time. Not all group members contributed to the report.		The group used the available time responsibly most of the time. There was an equal contribution by almost all group members to the report.	-The group used and managed all of their time responsibly. -There was an equal contribution by all group members to the report.		